

REVISED GUIDELINES FOR THE DISPOSAL OF DREDGED SPOILS

Introduction

1. These guidelines are designed to assist Contracting Parties in the management of dredged spoil in a way that will prevent pollution of the marine environment. In accordance with the mandate of the Helsinki Commission, the guidelines specifically address the disposal of dredged spoil by deposition or dumping in marine and estuarine waters.

2. It should be recognized that both removal and disposal of dredged sediments may cause harm to the marine environment. Consequently, Contracting Parties are encouraged to exercise control over dredging operations, in particular to ensure that the choice of dredging equipment will minimize the suspension of contaminants and fine sediments at the dredge site. Advice on environmentally acceptable dredging techniques is available from a number of international organisations including the Permanent International Association of Navigation Congresses (PIANC) 1986: Disposal of Dredged Material at Sea (LDC/SG9/2/1).

3. The Guidelines are presented in two parts. Part A deals with the assessment and management of dredged spoil disposal, while part B provides guidance on the design and conduct of monitoring of marine and estuarine disposal sites. In this context, it should be noted that, for each permitted dredging operation, regulatory agencies should conclude their assessment with a concise Impact Hypothesis (see Part B, paragraphs 5-11). This Impact Hypothesis will provide the principle basis for the design of post-operational monitoring activities.

4. The Guidelines commence with a summary of those Articles and Annexes to the Helsinki Convention which relate to the control of dredging activities followed by guidance on the conditions under which permits might be issued. Sections 3, 5 and 6 address the relevant considerations of Annex V of the Convention. Section 4 provides additional guidance on the sampling and analysis of dredged spoil.

PART A: ASSESSMENT AND MANAGEMENT OF DREDGED SPOIL

1. BACKGROUND

1.1 Contracting Parties shall prohibit the dumping of dredged spoil containing substances listed in Annex 1 of the Oslo Convention (appended to these Guidelines), unless the dredged material can be exempted because the substances are considered trace contaminants.

1.2 In accordance with Article 9 (2) of the Helsinki Convention, Contracting Parties shall issue special permits for the dumping of dredged spoil.

1.3 The provisions of Annex V to the Convention shall be applied when permits for the dumping of dredged spoil are issued in accordance with Article 9 (2).

1.4 These guidelines for the management of dredging activities, which include advice on dredged spoil sampling and analysis, have been prepared for the purpose of providing guidance to the Contracting Parties on:

- .1 the fulfilment of their obligations to issue permits for the dumping of dredged spoil in accordance with the provisions of the Convention;
- .2 the provision of reliable data on the input of contaminants to Convention waters by the dumping of dredged spoil;
- .3 the interpretation of key terms contained in the annexes, such as trace contaminants and significant quantities.

2. CONDITIONS UNDER WHICH PERMITS FOR DUMPING OF DREDGED SPOIL MAY BE ISSUED

2.1 In order to define the conditions under which permits for dumping of dredged spoil may be issued, Contracting Parties should develop criteria on a national basis, which meet the provisions of Articles 5 and 9 (2) of the Helsinki Convention.

2.2 These criteria may be described in terms of:

- .1 chemical characteristics and/or biological effects (e.g. sediment quality criteria);
- .2 reference data linked to particular methods of disposal or disposal sites;
- .3 specific environmental effects that are considered undesirable outside designated disposal sites;
- .4 the contribution of disposal to local contaminant fluxes.

2.3 Criteria should be derived from studies of sediments that have similar geochemical properties to those from the ones to be dredged and/or to those of the receiving system. Thus, depending upon natural variation in sediment geochemistry, it may be necessary to develop individual sets of criteria for each area in which dredging or disposal is conducted.

2.4 In the event that the criteria and the associated regulatory limits cannot be met, a Contracting Party should not issue a permit unless a detailed consideration of Annex V indicates that sea disposal is, nonetheless, the option of least detriment. If such a conclusion is drawn, a Contracting Party should:

- .1 provide for the realisation of a source-reduction programme where there is a source to reduce, with a view to meeting the established criteria;
- .2 take all practical steps to mitigate the impact of the dumping operation on the marine and estuarine environment including, for example, the use of containment or treatment methods;
- .3 prepare a detailed impact hypothesis;
- .4 initiate monitoring designed to verify any predicted adverse effects of the dumping;
- .5 issue a special permit.

When it is unlikely that disposal management techniques will alleviate the harmful effects of contaminated materials (see Section 7), containment and/or treatment technologies may be used to avert environmental damage. In such cases, selective dredging or separation of the more contaminated fractions (e.g. by use of hydrocyclones) may be employed to minimize the quantities of material for which such measures are required.

2.5 With a view to evaluating the possibilities for harmonizing or consolidating criteria referred to in § 2.1-2.4 above, including any sediment quality criteria, Contracting Parties are requested to inform the Helsinki Commission through the EC of the criteria adopted, as well as the scientific basis for the development of these criteria.

2.6 An important element of these guidelines for the management of dredging activities is the preparation of an Impact Hypothesis for each marine disposal operation. In concluding their assessments of the environmental implications of these operations, prior to the issue of a permit, Contracting Parties should formulate impact hypotheses in accordance with the guidance provided in Part B, paragraphs 6 - 9.

3. ASSESSMENT OF THE CHARACTERISTICS AND COMPOSITION OF DREDGED SPOIL (according to Annex V, Regulations 3 and 4)

Quantity and composition of dredged spoils to be dumped

3.1 For all dredged spoil to be disposed of at sea the following information should be obtained:

- gross wet tonnage requested
- method of dredging

- visual determination of sediment characteristics (clay-silt/sand/gravel/boulder)

3.2 In order to assess the capacity of the area for receiving dredged spoil both the total amount of material and the anticipated or actual loading rate at the disposal site should be taken into consideration.

3.3 In the absence of appreciable pollution sources, dredged spoil may be exempted from the testing referred to in paragraphs 3.5 and 3.8 of these Guidelines if it meets one of the criteria listed below; in such cases only the provisions of sections 5 and 6 should be taken into account:

- .1 Dredged spoil is composed almost exclusively of sand, gravel or rock; such materials are frequently found in areas of high current or wave energy such as streams with large bed loads or coastal areas with shifting bars and channels;
- .2 Dredged spoil is for beach nourishment or restoration and is composed predominantly of sand, gravel, or shell with particle sizes compatible with material on the receiving beaches; and
- .3 In the absence of appreciable pollution sources, dredged spoil not exceeding 10.000 tonnes per year from small, isolated and single dredging operations may be exempted only where this can be supported by existing local information on sediment quality.

In the case of capital dredging projects, national authorities may take account of the nature of the material to be disposed of to sea in exempting part of the material from the provisions of these guidelines relating to sampling and analysis. On the other hand, capital dredging removed from areas which may include contaminated sediments should be subject to characterization in accordance with these guidelines, notably paragraph 3.5

Physical, chemical, biochemical and biological properties

3.4 For dredged spoil that does not meet the exemptions in paragraph 3.3, further information will be needed to fully assess the impact. Information may be available from existing sources, for example from field observations on the impact of similar material at similar sites or from previous test data on similar material tested not more than five years previously, and knowledge of local discharges or other sources of pollution, supported by a selective analysis.

3.5 Chemical characterization will be necessary as a first step to estimate gross loading of contaminants, especially for new arisings of dredged spoil. The Commission's requirements for the elements and compounds to be analysed are set out in paragraphs 4.11 to 4.12.

3.6 Where it can be established that the material to be dumped is substantially similar in chemical and physical properties to the sediments at the proposed disposal site, the biological testing described in paragraph 3.8 may not be necessary providing the cumulative impacts at the disposal site will not exceed the environmental management objectives for the area concerned.

Contents of substances which are toxic, persistent or liable to accumulation in biological materials or sediments

3.7 The purpose of testing under this section is to establish whether the disposal at sea of dredged spoil containing Annex I and II substances might cause undesirable effects, especially the possibility of chronic or acute toxic effects on marine organisms or human health, whether or not arising from their bioaccumulation in marine organisms and especially in food species.

3.8 The following biological test procedures might not be necessary if the previous characterization of the material and of the receiving area allows an assessment of the environmental impact.

If, however, the previous analysis of the material shows the presence of Annex I or Annex II substances in considerable quantities or of substances whose biological effects are not understood, and if there is concern for antagonistic or synergistic effects of more than one substance, or if there is any doubt as to the exact composition or properties of the material, it may be necessary to carry out suitable biological test procedures. These procedures may include the following:

- acute toxicity tests;
- chronic toxicity tests capable of evaluating long-term sublethal effects, such as bioassays covering an entire life cycle; and
- tests to determine the potential for bioaccumulation of the substance of concern.

Chemical and physical changes of the dredged spoil after dumping, including possible formation of new compounds

3.9 Substances in dredged spoil may undergo physical, chemical and biochemical changes when entering the marine environment. The susceptibility of dredged spoil to such changes should be considered in the light of the eventual fate and potential effects of the dredged spoil. This may be reflected in the Impact Hypothesis and also in a monitoring programme.

Probability of production of taints reducing marketability of resources (fish, shellfish, etc.)

3.10 Proper dump site selection rather than a testing application is recommended. Site selection to minimize impact on commercial or recreational fishery areas is a major consideration in resource protection.

4. GUIDELINES ON DREDGED SPOIL SAMPLING AND ANALYSIS

Sampling for the purpose of issuing a dumping permit

4.1 For dredged spoil which requires analysis (i.e. which is not exempted under the Guidelines in paragraph 3.3), the following guidelines indicate how sufficient analytical information may be obtained for permitting purposes. Judgement and knowledge of local conditions will be essential in the application of these guidelines to any particular operation (see paragraph 4.10).

4.2 An in situ survey of the area to be dredged should be carried out. The distribution and depth of sampling should reflect the size of the area to be dredged, the amount to be dredged and the expected variability in the horizontal and vertical distribution of contaminants. Core samples should be taken where the depth of dredging and expected vertical distribution of contaminants warrant; otherwise a grab sample is considered appropriate. Sampling from barges is not advisable.

4.3 The following table gives an indication as to suitable numbers of separate stations to be sampled to obtain representative results assuming a reasonably uniform region to be dredged:

<u>Amount dredged m³</u>	<u>Number of Stations</u>
Up to 25 000	3
25 000 - 100 000	4 - 6
100 000 - 500 000	7 - 15
500 000 - 2 000 000	16 - 30
> 2 000 000	extra 10/million m ³

The number of stations should be adjusted according to the exchange characteristics of the area, e.g. less for open areas and more for enclosed and semi-enclosed areas.

4.4 Normally, the samples from each location should be analysed separately. However, if the sediment is clearly homogeneous with respect to sediment features (grain size, fractions and organic matter) and expected level of contaminations, it may be possible to composite samples from adjacent locations, two or more at a time, provided care has been taken to ensure that the results give a justified mean value for the contaminants. The original samples should be retained until the permitted operation has been completed, should the results indicate that further analysis is necessary.

Frequency of sampling

4.5 If a survey indicates that the material is essentially clean, surveys need not be repeated more frequently than once every 3 years.

4.6 It may be possible on the basis of the initial survey to reduce the number of sampling stations and/or the number of parameters while still providing sufficient information to confirm the initial analysis for issuing permits. If such a reduced sampling programme does not confirm the earlier analysis, the full survey should be repeated. If the list of parameters for repetitive measurement is reduced, a further analysis of the complete list is advisable at 5 year intervals.

4.7 In areas where there is a tendency for sediments to show high levels of contamination, or where contaminant distribution changes rapidly in response to varying environmental factors, analysis of the relevant contaminants should be frequent and linked to the permit renewal procedure.

Provision of Input Data

4.8 The sampling scheme described above provides information for permitting purposes. However, the scheme should at the same time provide a suitable basis for the estimation of total inputs and, for the time being, can be considered the most accurate approach available for this purpose. In this context, it is assumed that materials exempted from analysis represent insignificant inputs of contaminants and therefore it is not necessary to calculate or to report contaminant loads.

Determinants and methods

4.9 Analysis should normally be carried out on the whole sample but material greater than 2 mm grain size should be excluded. It will also be necessary, in order to allow assessment of data on contaminant levels in terms of their likely impact, to provide information on:

- density (taking into account sampling collection and handling)
- per cent solids
- grain size fractions (% sand, silt, clay)
- total organic carbon (TOC) below 2 mm.

4.10 In those cases where analysis is required, it should be mandatory for substances listed in Annexes I and II (see also Para 4.6). Other hazardous contaminants should also be measured if they are likely to be present on a result of local inputs.

4.11 In addition the permitting authority should carefully consider specific local inputs including the likelihood of contamination e.g. by arsenic, oils, PAH and triorganotins. The authority should make provision for the analysis of these substances as necessary.

4.12 Further guidance on the selection of determinands and methods of contaminant analysis in localized circumstances, and on procedures to be used for normalization and quality assessment purposes, will be found in the Technical Annexes to these guidelines.

5. CHARACTERISTICS OF DUMPING SITE AND METHOD OF DEPOSIT

(according to Annex V, Regulations 3 and 4)

5.1 Matters relating to dump site selection criteria are addressed in greater detail in studies prepared by GESAMP [1] (Reports and Studies no. 16: Scientific Criteria for the Selection of Waste Disposal Sites at Sea, IMO 1982) and by ICES [2] (Ninth Annual Report of the Oslo Commission, Annex 6).

- **Location, depth and distance from coast**
- **Location in relation to areas of special interest (amenity areas, spawning, nursery and fishing areas, etc.)**

5.2 Basic site characterization information to be considered by national authorities at a very early stage of assessment of a new site should include the co-ordinates of the dumping area (latitude, longitude), as well as its location with regard to:

- [1] IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution
- [2] International Council for the Exploration of the Sea.

- distance to nearest coastline
- recreational areas
- spawning and nursery areas
- known migration routes of fish or marine mammals
- sport and commercial fishing areas
- areas of natural beauty or significant cultural or historical importance
- areas of special scientific or biological importance (marine sanctuaries)
- shipping lanes
- military exclusion zones
- engineering uses of seafloor (e.g. potential or ongoing seabed mining, undersea cables, desalination or energy conversion sites).

Method of dumping

5.3 For dredged spoils, the only data to be considered under this item should include information on:

- disposal method (e.g. hopper discharge; discharge through pipes)
- dredging method (e.g. hydraulic or mechanical).
- **Dispersal characteristics (e.g. effects of currents and wind, and horizontal transport and vertical mixing)**
- **Existence and effects of other dumping which may have been carried out in the dumping area**

5.4 For the evaluation of dispersal characteristics, data should be obtained on the following:

- water depths (maximum, minimum, mean)
- water stratification in various seasons and weather conditions (depth and seasonal variation of pycnocline)
- tidal period, orientation of tidal ellipse, velocities of minor and major axis
- mean surface drift (net): direction, velocity
- mean bottom drift (net): direction, velocity
- storm (wave) induced bottom currents (velocities)
- wind and wave characteristics, average number of storm days per year
- concentration and composition of suspended solids.

5.5 The basic assessment of a site, either a new or an existing one, shall include the consideration of possible effects that might arise by the increase of certain constituents or by interaction (e.g. synergistic effects) with other substances introduced in the area, either by other dumpings or by river input and discharges from coastal areas, by exploitation areas and maritime transport, as well as through the atmosphere. The existing stress on biological communities as a result of such activities should be evaluated before any new or additional disposal operations are established. The possible future uses of the sea area should be kept under consideration.

5.6 Information from baseline and monitoring studies at already established dumping sites will be important in this evaluation of any new dumping activity at the same site or nearby.

5.7 The use of dispersive sites for the disposal of sediments with low levels of contamination is not devoid of environmental risk and requires consideration of the fate and effects of dispersed material. Nevertheless, there is evidence to suggest that at certain well-chosen estuarine sites, dredged spoil may enhance the habitats for desired species. The use of open-sea sites at distant off-shore locations is seldom an environmentally desirable solution to the prevention of marine pollution by dredged spoil.

General considerations and conditions:

Possible effects on amenities (e.g. floating or stranded material, turbidity, objectionable odour, discolouration and foaming)

5.8 Particular attention should be given to dredged spoil containing significant amounts of oil or substances that have a tendency to float following re-suspension in the water column. Such materials should not be dumped in a manner or at a location which may lead to interferences with fishing, shipping, amenities or other beneficial uses of the marine environment.

5.9 The disposal of dredged spoil should not interfere with, or devalue, legitimate commercial and economic uses of the marine environment. The selection of disposal sites should take into account the nature and extent of both commercial and recreational fishing activities as well as the spawning, nursery and feeding areas that sustain them.

5.10 In selecting disposal sites, the habitats of rare, vulnerable or endangered species should be avoided.

5.11 Besides toxicological and bioaccumulation effects of waste constituents, other potential impacts on marine life, such as nutrient enrichment, oxygen depletion, turbidity, modification of the sediment composition and blanketing of the sea floor, should be addressed.

5.12 It should also be taken into account that disposal at sea of certain substances may disrupt the sensory capabilities of the fish and may mask natural characteristics of sea water or tributary streams, thus confusing migratory species which i.a. fail to find spawning grounds or food.

6. MANAGEMENT OF THE PHYSICAL IMPACT OF DREDGED SPOIL DISPOSAL

Nature of the impact

6.1 All dredged spoils, whether or not contaminated, have a significant physical impact at the point of disposal. This impact includes covering of the seabed (and smothering of benthic organisms) and local enhancement of suspended solids levels. Physical impact may also result from the onward transport particularly in finer fractions, by wave and tidal action and residual current movements. In relatively enclosed waters, such as some estuarine and fjordic situations, oxygen consuming sediments (e.g. organic carbon-rich) could adversely affect the oxygen regime of receiving systems.

6.2 In the open sea, blanketing of the seabed is usually the most significant physical effect. The impact of dredged spoil on the suspended solids regime in most coastal waters often will be transient or negligible.

6.3 Biological consequences of these physical impacts include smothering of benthic organisms in the dumping area. Disposal may in certain special circumstances interfere with migration of fish (e.g. the impact of high turbidity on salmonoids in estuarine areas) or of crustacea (e.g. if deposition occurred in the coastal migration path of crabs).

6.4 An important consequence of the physical presence of dredged spoil disposal activities is interference with fishery activities and, in some instances, with navigation and recreation. The former relates to both smothering of areas potentially used for fisheries and interference with fixed fishing gear; shoaling following dumping can lead to navigational hazards and clay or silt deposition may be a nuisance in recreational areas. These problems can be aggravated if the spoil is contaminated with bulky harbour debris such as wooden beams, scrap metal, pieces of cable etc.

Approaches to management

6.5 This section deals only with management techniques to minimize the physical effects of dredged spoil disposal. Measures to control the contamination of dredged spoils are covered in other sections of these Guidelines.

6.6 The key to management lies in careful site selection (see section 5) and assessment of conflict between marine resources and activities. These notes are intended to supplement these considerations.

6.7 In most cases, blanketing of an area of seabed is accepted as an environmental cost of disposal. To avoid excessive use of the seabed, the number of sites should be limited as far as possible and each site should be used to the maximum extent possible without interfering with navigation. Once deposition stops, hydrodynamic forces will resort the nature of the sediments and re-colonisation is usually rapid. In some cases, it is noted that old spoil sites become productive new fishing areas.

6.8 Effects can be minimized by ensuring as far as possible that the sediments in the dredged spoil and receiving area are similar. Locally, biological impact may be further reduced if the deposition area is naturally subject to physical disturbance. Where this is not possible, consideration should be given where clean, fine materials are concerned to a deliberately dispersive style of disposal to reduce blanketing on a small site.

6.9 With capital and maintenance dredgings, the material may be different in character to the sediments at the receiving site and colonisation may be less rapid. Where bulky material such as rock and clay material is deposited, there may be interference with fishing activity, even in the long term. It may prove possible to use capital materials in the construction of artificial reefs for fishery or recreational purposes or for habitat creation; in this case, advice from ecologists or fishery biologists is essential.

6.10 The infilling of depressions or deliberate capping of dredged spoil deposits may be used in certain circumstances to avoid interferences with fishery or other legitimate activities.

6.11 Interference with fish or crustacea migration or spawning or with seasonal fishery activity may be avoided by timing restrictions on disposal activity. Trench digging and refilling activities may also interfere with migratory patterns; similar controls are appropriate. In mitigating the impact of disposal within estuaries on migrating fish, silt screens have been used to reduce the suspended solids levels, but these have proved hard to manage effectively.

6.12 Disposal vessels and operations should be inspected regularly to ensure that the conditions of the disposal permit are being complied with and that the crew are aware of their responsibilities under the permit. Where rubbish is a problem, it may be necessary to specify that the disposal vessel (or dredger) is fitted with a grid to facilitate removal for disposal (or recovery) on land, rather than being dumped at sea. Ships' records should be inspected to ensure that disposal is taking place at the specified disposal site.

6.13 Monitoring is an essential component of management action (see Part B).

Consideration of practical availability of alternative means of disposal or elimination

6.14 In the special case of dredged spoil, sea disposal is often an acceptable disposal option, though opportunities should be taken to encourage the productive use of dredged spoil for, for example, marsh creation, beach nourishment, land reclamation or use in aggregates.

6.15 For contaminated dredged spoils, consideration should be given to the use of special methods to mitigate their impact, in particular with respect to contaminant inputs. Containment methods may be required in extreme cases of contamination and very careful consideration should be given to a comparative assessment of

- human health risk
- environmental costs
- hazard (including accident) associated with treatment, transport and disposal
- economics including energy costs
- exclusion of future uses of disposal areas

for each disposal option.

6.16 If the foregoing analysis shows a land alternative to be more acceptable, a licence for sea disposal should not be given.

7. DISPOSAL MANAGEMENT TECHNIQUES

7.1 Ultimately, the problems of contaminated dredged spoil disposal can be controlled effectively only by control of discharges to waters from which dredged spoils are taken. Until this objective is met and for cases where there is historical contamination, the problems of contaminated dredged spoil may be addressed by using disposal management techniques.

7.2 "Disposal management techniques" refers to actions and processes through which the impact of persistent and potentially toxic substances contained in dredged spoil may be reduced to, or controlled at, a level which does not constitute a hazard to human health, harm to living resources and marine life, damage to amenities or interference with other legitimate uses of the sea. In this context they may, in certain circumstances, constitute additional methods by which dredged spoil containing organohalogenes or many other toxic substances may be rendered biologically harmless and which may constitute "special care" in the disposal of dredged spoil containing Annex II substances.

7.3 Relevant techniques include the utilization of natural physical, chemical and biological processes as they affect dredged spoil in the sea; for organic material these may include physical, chemical or biochemical degradation and/or transformation that results in the material becoming non-persistent, non-toxic and/or non-biologically available. Beyond the considerations of Annex V disposal management techniques may include burial on or in the sea floor followed by clean sediment capping, utilization of geochemical interactions and transformations of substances in dredged spoil when combined with sea water or bottom sediment, selection of special sites such as in abiotic zones, or methods of containing of the material in a stable manner (including on artificial islands).

7.4 Utilization of such techniques must be carried out in full conformity with other Annex V considerations, such as comparative assessment of alternative disposal options, and these Guidelines should always be associated with post-disposal monitoring to assess the effectiveness of the techniques and the need for any follow-up management action.

PART B: MONITORING DREDGED SPOIL DISPOSAL OPERATIONS

Definition

1. In the context of assessing and regulating environmental and human health impacts of dredged spoil disposal operations monitoring is the repeated measurement of a contaminant or an effect whether direct or indirect in the marine environment.

Objectives

2. Monitoring of dredged spoil disposal operations is generally undertaken for the following reasons:
 - i) to establish whether licensing conditions have, as intended, prevented adverse effects on the receiving area as a consequence of dumping;
 - ii) to improve the basis on which licence applications are assessed by improving knowledge of field effects from large discharges which are not readily estimated by laboratory or literature assessment;
 - iii) to provide the necessary evidence to demonstrate within the framework of the Convention that the control measures applied are sufficient to ensure that the dispersive and assimilative abilities of the marine environment are not exceeded, so causing environmental damage.
3. The purposes of monitoring are to determine contaminant levels in organisms, the biological effects and consequences for the marine environment due to the dumping of dredged spoil, and, ultimately, to allow managers to control exposures of the organisms of concern to dredged spoils and associated contaminants.

Strategy

4. Monitoring operations are expensive for they require considerable resources both at sea and in subsequent working up of samples. In order to approach the monitoring programme in a resource-effective manner, it is essential that the programme should have clearly defined objectives, that measurements made can meet those objectives, and that the results be reviewed at regular intervals in relation to those objectives. The monitoring scheme should then be continued, reviewed or even terminated, as appropriate.

Impact Hypothesis

5. In order to establish such objectives, it is first necessary to derive an Impact Hypothesis describing predicted effects on the physical, chemical and biological environment.
6. An Impact Hypothesis should integrate information on the characteristics of the dredged spoil and proposed disposal site conditions. The aim is to provide a concise scientific analysis of the potential effects on human health, living resources, marine life, amenities and other legitimate uses of the sea. It should encompass both the temporal and spatial scales of potential effects.
7. The preliminary evaluation should be as comprehensive as possible. The primary areas of potential impact should be identified and are those considered to have the most serious consequences for human health and the environment. Alterations to the physical environment, risks to human health, devaluation of marine resources, and interference with other legitimate uses of the sea are often seen as priorities in this regard.
8. The expected consequences of disposal (targets) could be described in terms of habitats, processes, species, communities and uses affected. The precise nature of the change, response, or interference (effect) predicted could then be described. The target and the effect together could be described (quantified) in sufficient detail so that there would be no doubt as to the parameters to be measured during post-operational monitoring. In the latter context, it might be essential to determine "where" and "when" the impacts can be expected.
9. In order to develop this hypothesis, it may be necessary to conduct a baseline survey which describes not only the environmental characteristics, but also the variability of the environment. It may also be helpful to develop computer models of the environment, to determine possible effects of disposal. Then, before any programme is drawn up and any measurements are made, the following questions should be addressed:
 - i) what exactly should be measured;
 - ii) what is the purpose of monitoring a particular variable, contaminant or biological effect;
 - iii) in what compartment or at which locations can measurements most effectively be made;
 - iv) for how long should the measurements continue to be made to meet the originally defined aim;
 - v) what should be the temporal and spatial scale of measurements made to test the hypothesis.
10. It is recommended that the choice of contaminants to be monitored should depend primarily on the ultimate purposes of monitoring. One should certainly not have to monitor regularly for all contaminants at all sites and it should not be necessary to use more than one substrate or effect to meet each aim.
11. A major requirement is to develop criteria describing the specific environmental effects of dredging that should be prevented outside designated dredging and disposal areas (see Part A, section 2).

Monitoring

12. The disposal of dredged spoil has its primary impact at the seabed. Thus although a consideration of water column effects cannot be discounted in the early stages of monitoring planning, it is often possible to restrict subsequent monitoring to the seabed.
13. Where it is considered that effects will be largely physical, monitoring may be based on remote methods such as sidescan sonar to identify changes in the character of the seabed and bathymetric techniques (e.g. echosounding) to identify areas of dredged spoil accumulation. Both of these techniques will require a certain amount of sediment sampling to establish ground-truth.

14. Chemical measurements may also prove useful to trace the dispersal of the dredged spoil and assess any minor accumulation of material not detected by bathymetric surveys.
15. When a contaminated dredged spoil is deposited, it may be necessary to measure its chemical components to ensure that unacceptable accumulation of these components does not occur.
16. Where either physical or chemical effects at the seabed are expected, it will be necessary to examine the benthic community structure in areas where the dredged spoil disperses. In the case of chemical effects it may also be necessary to examine the chemical quality of the biota (including fish).
17. In order to assess the impact it will be necessary to compare the physical, chemical or biological quality of the affected areas with reference sites located away from dredged spoil dispersal pathways. Such areas can be identified during the early stages of the impact assessment.
18. The spatial extent of sampling will need to take into account the size of the area designated for dumping, any areas of possible short dumping, the mobility of the dumped dredged spoil and water movements which will determine the direction and extent of sediment transport. It may be possible to limit sampling within the disposal site itself as effects in this area are accepted and their definition in detail may be unnecessary. However, some sampling should be carried out to aid the identification of the type of effect which may be expected in other areas and for scientific rigour.
19. The frequency of survey will depend on a number of factors. Where a disposal operation has been going on for several years it may be possible to establish the effect at a steady state of input and repeated surveys would only be necessary if changes are made to the operation (quantities or type of dredged spoil deposited, method of disposal etc.).
20. If it were decided to monitor the recovery of an area which was no longer used for dredged spoil disposal, more frequent measurement might be needed.
21. Since the effects of dredged spoil disposal are likely to be similar in many areas, there appears to be little justification for monitoring all sites, particularly those receiving small quantities of dredged spoil. It would be more effective to carry out more detailed investigations at a few carefully chosen sites (e.g. those subject to large inputs of dredged spoil) to increase understanding of effects and processes.
22. Concise statements of monitoring activities should be prepared. Reports should detail the measurements made, results obtained and how these data relate to the monitoring objectives. The frequency of reporting will depend upon the scale of disposal activity and the intensity of monitoring. Contracting Parties should inform the Secretariat of their monitoring activities and submit reports when they are available.

Annex I

NOTE: This document has been superseded and is not applicable any more under the OSPAR Convention.

The following substances are listed for the purpose of Article 5 of the Convention ;

1. Organohalogen compounds and compounds which may form such substances in the marine environment, excluding those which are non-toxic, or which are rapidly converted in the sea into substances which are biologically harmless ;
2. Substances which have been agreed between the Contracting Parties as likely to be carcinogenic under the conditions of disposal ;
3. Mercury and mercury compounds ;
4. Cadmium and cadmium compounds ;
5. Persistent plastics and other persistent synthetic materials which may float, or remain in suspension, or sink to the bottom, and which may seriously interfere with marine life, fishing, navigation, amenities or with other legitimate uses of the sea .

**TECHNICAL SUPPLEMENTS TO THE OSLO COMMISSION
GUIDELINES FOR THE MANAGEMENT OF DREDGED MATERIAL**

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Technical Annex 1:

Analytical Requirements for Dredged Material Assessment

1. This Annex amplifies the analytical requirements set out in paragraphs 4.9 - 4.12 of the HELCOM Guidelines for the Disposal of Dredged Spoils.¹
2. A tiered approach to testing is recommended. At each tier it will be necessary to determine whether sufficient information exists to allow a management decision to be taken or whether further testing is required.
3. As a preliminary to the tiered testing scheme, information required under section 3.1 of the Guidelines will be available. In the absence of appreciable pollution sources and if the visual determination of sediment characteristics leads to the conclusion the dredged material meets one of the exemption criteria under paragraph 3.3 of the Guidelines then the material will not require further testing.
4. The sequence of tiers is as follows:
 - assessment of physical properties
 - assessment of chemical properties
 - assessment of biological properties and effects

A pool of supplementary information, determined by local circumstances may be used to augment each tier.

5. It is important that the assessment procedure must at each stage take account of the method of analysis.

Tier I: PHYSICAL PROPERTIES.

It is strongly recommended that the following determinations are carried out:

- grain size (% sand, silt, clay)
- percent solids (dry matter)
- density/specific gravity
- organic matter (as total organic carbon)

Tier II: CHEMICAL PROPERTIES

Primary group determinands:

In all cases when chemical analysis is required the concentrations of the following trace metals should be determined:

Cadmium (Cd)	Copper (Cu)	Mercury (Hg)	Zinc (Zn)
Chromium (Cr)	Lead (Pb)	Nickel (Ni)	

¹ modified for HELCOM purposes

In addition the concentrations of the following polychlorinated biphenyl (PCB) congeners should be determined:

IUPAC nos 28, 52, 101, 118, 138, 153 and 180.

Analysis should be carried out on the whole sediment (< 2mm).

It is recognised that determination of PCBs is indicated as mandatory in the Guidelines. However, the determination of PCBs will not be necessary when:

- there are no known sources (point or diffuse) of contamination or historic inputs; and
- the sediments are predominantly coarse; and
- the levels of total organic carbon are low.

If PCB analysis is undertaken information on each of the congeners on the ICES primary list should be reported to the Commission.

Secondary group determinands:

Based upon local information of sources of contamination (point sources or diffuse sources) or historic inputs, other determinands may be applicable, for instance:

arsenic	further chlorobiphenyls (IUPAC Nos 18, 31, 44, 66/95, 110, 149, 187 and 170)	organophosphorus pesticides	polycyclic aromatic hydrocarbons (PAHS)
oil	organochlorine pesticides	triorganotin compounds	polychlorinated dibenzodioxins (PCDDs)/polychlorinated dibenzofurans (PCDFs)

In deciding which individual organic contaminants to determine, reference should be made to existing priority substance lists, such as that prepared by the CEC*.

Tier III: BIOLOGICAL PROPERTIES AND EFFECTS

No guidance is offered at this stage

SUPPLEMENTARY INFORMATION

The need for this information will be determined by local circumstance and may form an essential part of the management decision. Appropriate data might include : redox potential, sediment oxygen demand, total nitrogen, total phosphorus, iron, manganese, mineralogical information or parameters for normalizing trace metal data (eg aluminium, lithium, scandium - see Technical Annex 2).

* Communication of 22 June 1982 from the Commission to the Council on hazardous substances within the meaning of List I of Council Directive 76/464/EEC. Official Journal of the European Communities C 176, 14.7.1982, p.3

Technical Annex 2:

Normalization techniques for studies on the spatial distribution of contaminants*

1. Introduction

Normalization in this discussion is defined as a procedure to compensate for the influence of natural processes on the measured variability of the concentration of contaminants in sediments. Most contaminants (metals, pesticides, hydrocarbons) show high affinity to particulate matter and are, consequently, enriched in bottom sediments of estuaries and coastal areas. In practice, natural and anthropogenic substances entering the marine system are subjected to a variety of biogeochemical processes. As a result, they become associated with fine-grained suspended solids and colloidal organic and inorganic particles. The ultimate fate of these substances is determined, to a large extent, by particulate dynamics. They therefore tend to accumulate in areas of low hydrodynamic energy, where fine material is preferentially deposited. In areas of higher energy, these substances are "diluted" by coarser sediments of natural origin and low contaminant content.

It is obvious that the grain size is one of the most important factors controlling the distribution of natural and anthropogenic components in the sediments. It is, therefore, essential to normalize for the effects of grain size in order to provide a basis for meaningful comparisons of the occurrence of substances in sediments of various granulometry and texture within individual areas or among areas. Excess levels, above normalized background values, could then be used to establish sediment quality.

For any study of sediments, a basic amount of information on their physical and chemical characteristics is required before an assessment can be made on the presence or absence of anomalous contaminant concentrations. The concentration at which contamination can be detected depends on the sampling strategy and the number of physical and chemical variables that are determined in individual samples.

The various granulometric and geochemical approaches used for the normalization of trace elements data as well as the identification of contaminated sediments in estuarine and coastal sediments has been extensively reviewed by Loring (1988). Two normalization approaches widely used in oceanography and in atmospheric sciences have been selected here. The first is purely physical and consists of characterizing the sediment by measuring its content of fine material. The second approach is chemical in nature and is based on the fact that the small size fraction is usually rich in clay minerals, iron and manganese oxi-hydroxides and organic matter. Furthermore, these components often exhibit a high affinity for organic and inorganic contaminants and are responsible for their enrichment in the fine fraction. Chemical parameters (e.g., Al, Sc, Li) representative of these components may thus be used to characterize the small size fraction under natural conditions.

It is strongly suggested that several parameters be used in the evaluation of the quality of sediments. The types of information that can be gained by the utilization of these various parameters are often complementary and extremely useful considering the complexity and diversity of situations encountered in the sedimentary environment. Furthermore, measurements of the normalizing parameters selected here are rather simple and inexpensive.

This report presents general guidelines for sample preparation, analytical procedures, and interpretation of physical and chemical parameters used for the normalization of geochemical data. Its purpose is to

* Extract from the 1989 ACMP Report (Section 14). ICES Coop. Res. Rep. 167, pp 68-76

demonstrate how to collect sufficient data to normalize for the grain-size effect and to allow detection, at various levels, of anomalous concentrations of contaminants within estuarine and coastal sediments.

2. Sampling Strategy

Ideally, a sampling strategy should be based on a knowledge of the source of contaminants, the transport pathways of suspended matter and the rates of accumulation of sediments in the region of interest. However, existing data are often too limited to define the ideal sampling scheme. Since contaminants concentrate mainly in the fine fraction, sampling priority should be given to areas containing fine material that usually correspond to zones of deposition.

The high variability in the physical, chemical and biological properties of sediments implies that an evaluation of sediment quality in a given area must be based on a sufficient number of samples. This number can be evaluated by an appropriate statistical analysis of the variance within and between samples. To test the representativity of a single sediment specimen at a given locality, several samples at one or two stations should be taken.

The methodology of sampling and analysis should follow the recommendations outlined in the "Guidelines for the Use of Sediments as a Monitoring Tool for Contaminants in the Marine Environment" (ICES 1987). In most cases, the uppermost layer of sediments collected with a tightly closing grab sampler (Level I in the Guidelines) is sufficient to provide the information concerning the contamination of the sediments of a given area compared to sediments of uncontaminated locations or other reference material.

Another significant advantage of using sediments as monitoring devices is that they have recorded the historical evolution of the composition of the suspended matter deposited in the area of interest. Under favourable conditions, the degree of contamination may be estimated by comparison of surface sediments with deeper samples, taken below the biological mixing zone. The concentrations of trace elements in the deeper sediment may represent the natural background level in the area in question and can be defined as baseline values. This approach requires sampling with a box-corer or a gravity corer (Levels II and III in the Guidelines).

3. Analytical Procedures

Typical analytical procedures to be followed are outlined in Table 1. The number of steps that are selected will depend on the nature and extent of the investigation.

3.1 Grain size fractionation

It is recommended that at least the amount of material $<63 \mu\text{m}$, corresponding to the sand/silt classification limit, be determined. The sieving of the sample at $63 \mu\text{m}$ is, however, often not sufficient, especially when sediments are predominantly fine grained. In such cases, it is better to normalize with lower size thresholds since the contaminants are mainly concentrated in the fraction $<20 \mu\text{m}$, and even more specifically in the clay fraction ($<2 \mu\text{m}$). It is thus proposed that a determination be made, on a sub-sample, of the weight fraction $<20 \mu\text{m}$ and that $<2 \mu\text{m}$ with the aid of a sedimentation pipette or by elutriation. Several laboratories are already reporting their results relative to the content of fine fractions of various sizes and these results may be useful for comparison among areas.

3.2 Analysis of contaminants

It is essential to analyse the total content of contaminants in sediments if quality assessment is the goal of the study, and it is thus recommended that the unfractionated sample ($<2 \text{mm}$) be analysed in its entirety. The total content of elements can be determined either by non-destructive methods, such as X-ray

fluorescence or neutron activation, or by a complete digestion of the sediments (involving the use of hydrofluoric acid (HF)) followed by methods such as atomic absorption spectrophotometry or emission spectroscopy. In the same way, organic contaminants should be extracted with the appropriate organic solvent from the total sediment.

An individual size fraction of the total sediment may be used for subsequent analysis, if required, to determine the absolute concentrations of contaminants in that fraction, providing that its contribution to the total is kept in perspective when interpreting the data. Such size fraction information might be useful in tracing the regional dispersal of metals associated with specific grain-size fractions, when the provenance of the material remains the same. However, sample fractionation is a tedious procedure that introduces considerable risk of contamination and potential losses of contaminants due to leaching. The applicability of this approach is thus limited.

4. Normalization Procedures

4.1 Granulometric normalization

Since contaminants tend to concentrate in the fine fraction of sediments, correlations between total concentrations of contaminants and the weight percent of the fine fraction, determined separately on a sub-sample of the sediment by sieving or gravity settling, constitute a simple but powerful method of normalization. Linear relationships between the concentration and the weight percentage of the fine fraction are often found and it is then possible to extrapolate the relationships to 100% of the fraction studied, or to characterize the size dependence by the slope of the regression line.

4.2 Geochemical normalization

Granulometric normalization alone is inadequate to explain all the natural trace variability in the sediments. In order to interpret better the compositional variability of sediments, it is also necessary to attempt to distinguish the sedimentary components with which the contaminants are associated throughout the grain-size spectrum. Since effective separation and analysis of individual components of sediments is extremely difficult, such associations must rest on indirect evidence of these relationships.

Since contaminants are mainly associated with the clay minerals, iron and manganese oxi-hydroxides and organic matter abundant in the fine fraction of the sediments, more information can be obtained by measuring the concentrations of elements representative of these components in the samples.

An inert element such as aluminium, a major constituent of clay minerals, may be selected as an indicator of that fraction. Normalized concentrations of trace elements with respect to aluminium are commonly used to characterize various sedimentary particulate materials (see below). It may be considered as a conservative major element, that is not affected significantly by, for instance, early diagenetic processes and strong redox effects observed in sediments.

In the case of sediments derived from the glacial erosion of igneous rocks, it has been found that contaminant/Al ratios are not suitable for normalizing for granular variability (Loring, 1988). Lithium, however, appears to be an ideal element to normalize for the grain size effect in this case and has the additional advantage of being equally applicable to non-glacial sediments.

In addition to the clay minerals, Mn and Fe compounds are often present in the fine fraction, where they exhibit adsorption properties strongly favouring the incorporation of various contaminants. Mn and Fe are easily analysed by flame atomic absorption spectrometry and their measurement may provide insight into the behaviour of contaminants.

Organic matter also plays an important role as scavenger of contaminants and controls, to a major degree, the redox characteristics of the sedimentary environment.

Finally, the carbonate content of sediments is easy to determine and provides additional information on the origin and the geochemical characteristics of the sediments. Carbonates usually contain insignificant amounts of trace metals and act mainly as a diluent. Under certain circumstances, however, carbonates can fix contaminants such as cadmium and copper. A summary of the normalization factors is given in Table 2.

4.3 Interpretation of the data

The simplest approach in the geochemical normalization of substances in sediments is to express the ratio of the concentration of a given substance to that of the normalizing factor.

Normalization of the concentration of trace elements with respect to aluminium (or scandium) has been used widely and reference values on a global scale have been established for trace elements in various compartments: crustal rocks, soils, atmospheric particles, river-borne material, marine clays and marine suspended matter (cf., e.g., Martin and Whitfield, 1983; Buat-Menard and Chesselet, 1979).

This normalization also allows the definition of an enrichment factor for a given element with respect to a given compartment. The most commonly used reference level of composition is the mean global normalized abundance of the element in crustal rock (Clarke value). The enrichment factor EF is given by:

$$EF_{\text{crust}} = (X/Al)_{\text{sed}} / (X/Al)_{\text{crust}}$$

where X/Al refers to the ratio of the concentration of element X to that of Al in the given compartment.

However, estimates of the degree of contamination and time trends of contamination at each sampling location can be improved upon by making a comparison with metal levels in sediments equivalent in origin and texture.

These values can be compared to the normalized values obtained for the sediments of a given area. Large departures from these mean values indicate either contamination of the sediment or local mineralization anomalies.

When other variables (Fe, Mn, organic matter and carbonates) are used to characterize the sediment, regression analysis of the contaminant concentrations with these parameters often yields useful information on the source of contamination and on the mineralogical phase associated with the contaminant.

A linear relationship between the concentration of trace constituents and that of the normalization factor has often been observed (Windom et al., 1989). In this case and if the natural geochemical population of a given element in relation to the normalizing factor can be defined, samples with anomalous normalized concentrations are easily detected and may indicate anthropogenic inputs.

According to this method, the slope of the linear regression equation can be used to distinguish the degree of contamination of the sediments in a given area. This method can also be used to show the change of contaminant load in an area if the method is used on samples taken over intervals of some years (Cato, 1986).

A multi-element/component study in which the major and trace metals, along with grain size and organic carbon contents, have been measured allows the interrelationships between the variables to be established

in the form of a correlation matrix. From such a matrix, the most significant ratio between trace metal and relevant parameter(s) can be determined and used for identification of metal carriers, normalization and detection of anomalous trace metal values. Factor analyses can sort all the variables into groups (factors) that are associations of highly correlated variables, so that specific and/or non-specific textural, mineralogical, and chemical factors controlling the trace metal variability may be inferred from the data set.

Natural background levels can also be evaluated on a local scale by examining the vertical distribution of the components of interest in the sedimentary column. This approach requires, however, that several favourable conditions are met: steady composition of the natural uncontaminated sediments; knowledge of the physical and biological mixing processes within the sediments; absence of diagenetic processes affecting the vertical distribution of the component of interest. In such cases, grain-size and geochemical normalization permits compensation for the local and temporal variability of the sedimentation processes.

5. Conclusions

The use of the granulometric measurements and of component/reference element ratios are useful approaches towards complete normalization of granular and mineralogical variations, and identification of anomalous concentrations of contaminants in sediments. Their use requires that a large amount of good analytical data be collected and specific geochemical conditions be met before all the natural variability is accounted for, and the anomalous contaminant levels can be detected. Anomalous metal levels, however, may not always be attributed to contamination, but rather could easily be a reflection of differences in sediment provenance.

Geochemical studies that involve the determination of the major and trace metals, organic contaminants, grain size parameters, organic matter, carbonate, and mineralogical composition in the sediments are more suitable for determining the factors that control the contaminant distribution than the measurement of absolute concentrations in specific size fractions or the use of potential contaminant/reference metal ratios alone. They are thus more suitable for distinguishing between uncontaminated and contaminated sediments. This is because such studies can identify the factors that control the variability of the concentration of contaminants in the sediments.

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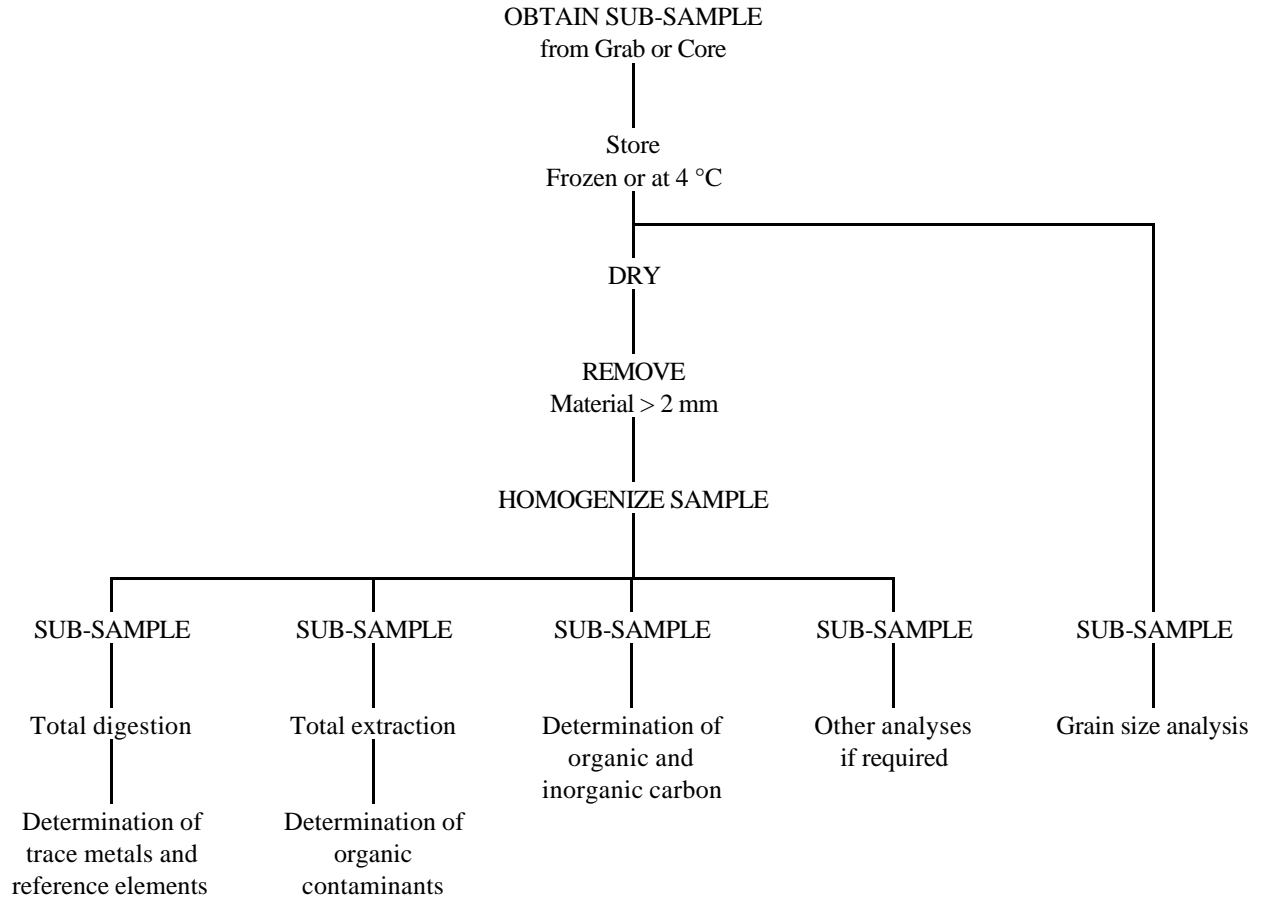
Table 1: A typical approach for determinations of physical and chemical parameters in marine sediments

Table 2: Summary of normalization factors

NORMALIZATION FACTOR	SIZE (μm)	INDICATOR	ROLE
<u>Textural</u>			
			Determines physical sorting and depositional pattern of metals
Sand	2000 - 63	Coarse-grained metal-poor minerals/compounds	Usually diluent of trace metal concentrations
Mud	< 63	Silt and clay size metal-bearing minerals/compounds	Usually overall concentrator of trace metals
Clay	< 2	Metal-rich clay minerals	Usually fine-grained accumulator of trace metals
<u>Chemical</u>			
Si		Amount and distribution of metal-poor quartz	Coarse-grained diluter of contaminants
Al		Al silicates, but used to account for granular variations of metal-rich fine silt and clay size Al-silicates	Chemical tracer of Al-silicates, particularly the clay minerals
Li, Sc		Structurally combined in clay minerals and micas	Tracer of clay minerals, particularly in sediments containing Al-silicates in all size fractions
Organic carbon		Fine-grained organic matter	Tracer of organic contaminants. Sometimes accumulator of trace metals like Hg and Cd
Fe, Mn		Metal-rich silt and clay size Fe-bearing clay minerals, Fe-rich heavy minerals and hydrous Fe and Mn oxides	Chemical tracer for Fe-rich clay fraction. High absorption capacity of organic and inorganic contaminants
Carbonates		Biogenic marine sediments	Diluter of contaminants. Sometimes accumulate trace metals like Cd and Cu

Technical Annex 3:

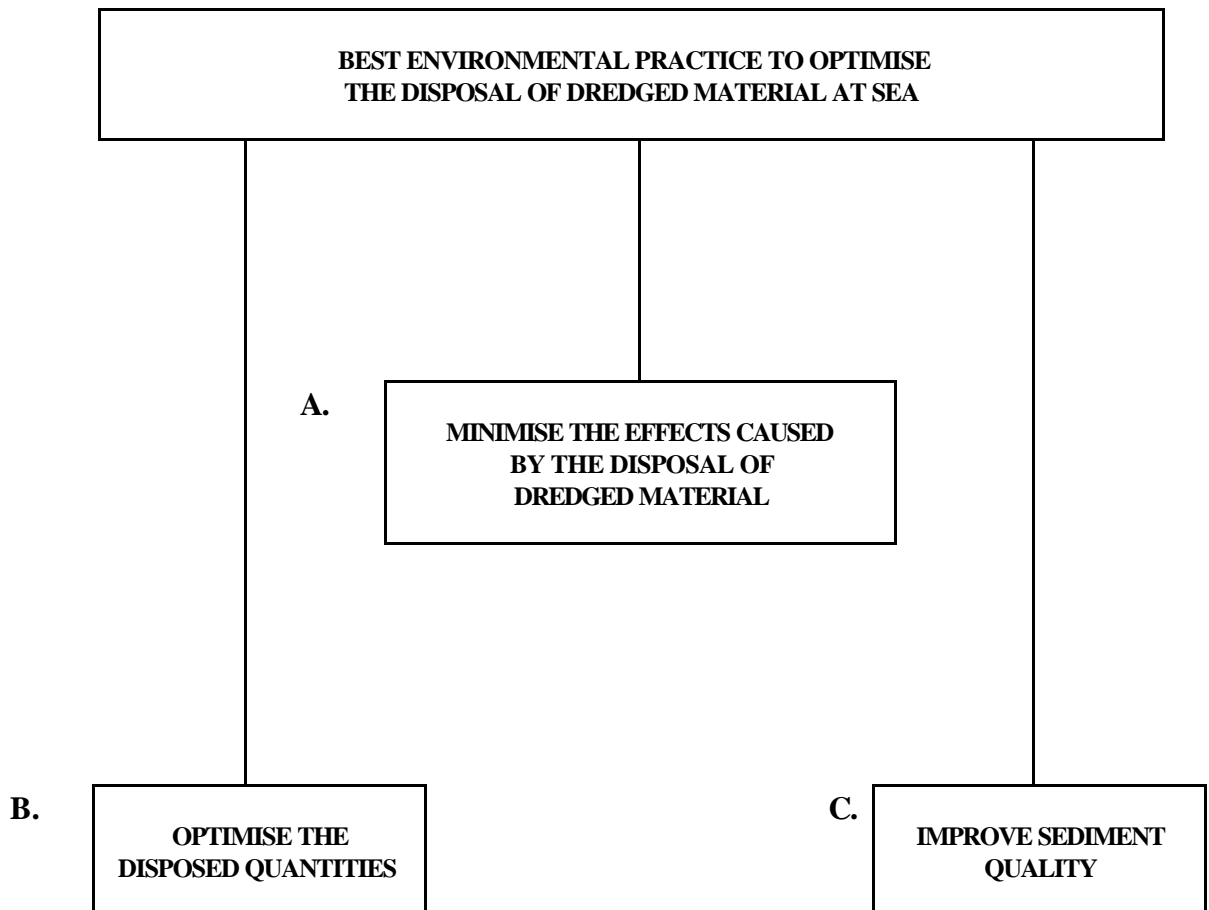
Best Environmental Practice (BEP)

Introduction

This technical annex was prepared bearing in mind that, although the guidelines strictly only apply to the disposal of dredged material, Contracting Parties are encouraged also to exercise control over dredging operations.

This technical annex has as its aim to provide guidance to national regulatory authorities, operators of dredging vessels and port authorities on how to minimise the effects on the environment of dredging and disposal operations.

The items given as BEP under the different headings of this annex are given as examples. Their applicability will generally vary according to the particular circumstances of each operation. Different approaches than those described in this annex may be appropriate: it is clear that for each operation the most appropriate practice must be used.

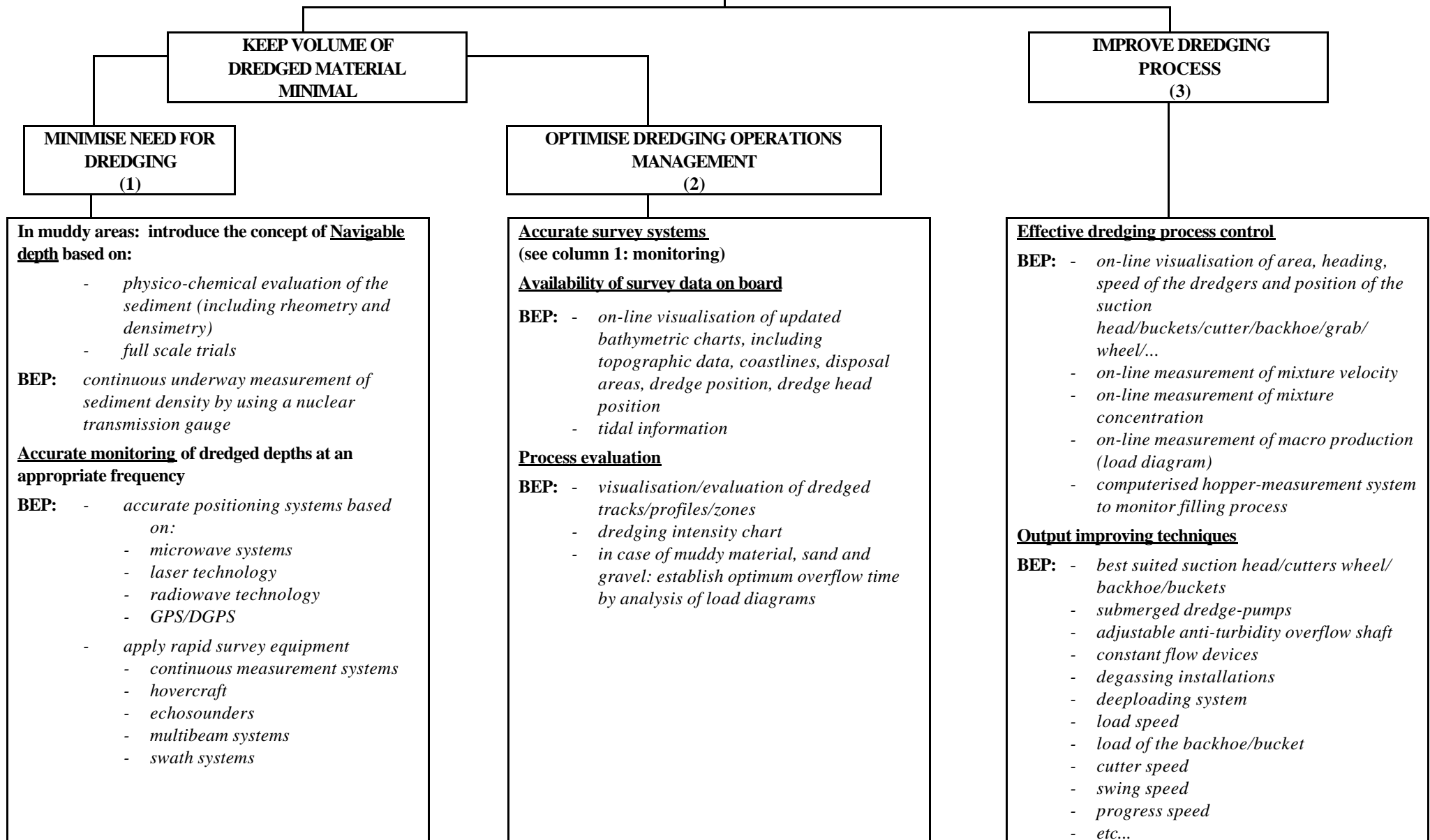


Point A - Minimisation of the effects caused by the disposal of dredged material - is comprehensively described in the main body of these guidelines.

Point B - Optimisation of the disposed quantities - and Point C - Improvement of sediment quality -, but are very relevant to the prevention of pollution of the marine environment resulting from the disposal of dredged materials. Descriptions of BEP in relation to these activities are given at Appendices I and II.¹

¹ modified for HELCOM purposes

OPTIMISE THE DISPOSED QUANTITIES



**IMPROVE SEDIMENT QUALITY
(PART A §§ 2.4 and 7.1 of the guidelines)**

**IN SITU BEFORE DREDGING
(4)**

Improve physico-chemical aspects (cohesion, consistency, density...) of dredged material, by introducing the navigable depth concept or by in-situ stabilisation of the bottom/fixation of contaminants

- BEP:** - *navigable depth: increase sediment density: see column 1*
- *underwater mixing or injection of stabilising or binding agents*
 - *on-line visualisation of position of mixing/injection equipment (see Appendix I, Column 2: Process evaluation, and column 3: Effective dredging process control)*

Bacteriological treatment:

In-situ decontamination of sediments containing organic contaminants

- BEP:** - *underwater mixing/injection of bacteria and nutrients*
- *on-line visualisation of position of mixing/injection equipment (see Appendix I, Column 2: Process evaluation, and column 3: Effective dredging process control)*

**IN THE HOPPER
(5)**

Mechanical separation

- BEP:** - *cyclones for separation of granulometric fractions*
- *dewatering (under development)*

Physico-chemical/bacteriological treatment (extraction of contaminants/mixing) during dredging operation or during transport

- BEP:** *under development*

**AFTER DISPOSAL
(6)**

Improving physico-chemical characteristics (cohesion, density, permeability, resistance ...) by in-situ stabilisation/fixation

- BEP:** - *underwater mixing or injection of stabilising/binding agents (under development)*
- *visualisation of the position of injection/mixing equipment*

Bacteriological treatment:

In-situ decontamination of sediments polluted by organic contaminants

- BEP:** - *underwater mixing/injection of bacteria and nutrients*
- *on-line visualisation of the position of injection/mixing equipment*